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Final Report for Cooperative Agreement Between NASA and Scripps Institution of Oceanography: Agreement No. NCC 2-820

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Summary of Research

During this cooperative agreement, our research has been focused on continued microphysical and radiative transfer modeling of upper tropospheric cirrus clouds. Using a two-stream radiative transfer code, we performed extensive sensitivity studies of the cloud radiative forcing due to high tropical cirrus. The sensitivities to cloud height, optical depth, and microphysical content were evaluated. In our publication of these results [Jensen et al., GRL, **21**, 2023–2026, 1994], we discussed the possible physical explanations for the balance between longwave and shortwave cloud radiative forcing observed by ERBE. We argued that the most likely explanation is that the radiative forcing is typically dominated by deep, optically thick cirrus, and that the observed variations in longwave and shortwave forcing components are due to variations in cloud cover.

We have also completed a sensitivity study of ice nucleation in the upper troposphere. Essentially, this study was a theoretical analysis of the possible cloud-aerosol feedback in the upper troposphere. Given the assumption that the ice nucleation in the upper troposphere is dominated by homogeneous freezing of sulfate aerosols, we showed that the number of ice crystals which nucleate should be relatively insensitive to the number of aerosols present [Jensen et al., GRL, **21**, 2019–2022, 1994]. We also found that the number of ice crystals nucleated should increase rapidly with decreasing temperature and increasing cooling rate. This sensitivity could explain the relatively large numbers of ice crystals observed in high tropical cirrus.

We have also been focusing considerable effort on modeling of subvisible cirrus near the tropical tropopause which were observed frequently during the CEPEX experiment over the western Pacific. The first objective of this work has been to understand the physical processes responsible for formation and persistence of these clouds. In particular, we want to understand why the subvisible cirrus is ubiquitous over the tropical western Pacific, but essentially absent at midlatitudes and at other tropical longitudes. We have modeled the genesis of the clouds due to both outflow from convective anvils and in situ nucleation near the tropopause. In a manuscript submitted to *Journal of Geophysical Research*, we argue that in situ nucleation near the tropical tropopause is likely, and large ice crystal number densities are likely due to the extremely low temperatures. The large ice number densities will limit crystal growth and allow the crystals to remain in narrow layers near the tropopause without precipitating out. We have shown that at the warmer midlatitude tropopause, fewer ice crystals should nucleate, resulting in more rapid cloud dissipation due to precipitation.

The second subvisible cirrus issue we have addressed is their possible impact on the stratospheric water budget. We have simulated ice cloud formation driven by motions on time scales ranging from gravity waves (1–2 hours) to continental-scale lifting (up to 24 hours). We show that in situ ice cloud formation due to gravity waves in the lower stratosphere will not likely dehydrate the region since the ice crystals do not grow large enough (5–10 μm) to precipitate out and remove the water. Cloud formation driven by slow lifting over a longer time period will allow more dehydration since fewer crystals should nucleate and the crystals will have longer to grow and fall out of the region near the tropopause. We also show that ice clouds which form in air slowly lifting near the tropopause may substantially reduce the flux of water vapor into the stratosphere (manuscript in preparation).

References

Jensen, E. J., and O.B. Toon, Ice nucleation in the upper troposphere: Sensitivity to aerosol number density, temperature, and cooling rate, *Geophys. Res. Lett.*, **21**, 2019–2022, 1994.

Jensen, E. J., S. Kinne, and O.B. Toon, Tropical cirrus cloud radiative forcing: Sensitivity studies, *Geophys. Res. Lett.*, **21**, 2023–2026, 1994.

Jensen, E. J., O. B. Toon, D. Spinhirne, H. B. Selkirk, On the formation and persistence of subvisible cirrus clouds near the tropical tropopause, submitted to *J. Geophys. Res.*, 1995.